

TREND ANALYSIS OF SEA LEVEL RISE FOR WEST COAST OF
PENINSULAR MALAYSIA

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ABSTRACT

Future sea level rise would be expected to have a number of impacts, particularly on Malaysia coastal systems such as flooding and inundation, coastal erosion and salt water intrusion. This study analyzes the trend variation of sea level rise (SLR) for selected locations along the west coast of Peninsular Malaysia. The rate of future SLR at these stations will then be predicted for the year 2050 and 2100. This study also examines the trend of sea level rise throughout the Straits of Malacca. The historical mean sea level data at the selected stations were used in the trend analysis. The non parametric Mann Kendal tests were carried out to determine trends in sea level rise. From the analysis, the results showed that all the selected stations along the West Coast of Peninsular Malaysia (i.e: Teluk Ewa Langkawi, Penang, Lumut, Port Klang, Tanjung Keling Melaka, and Kukup Johor) have an upward trend of sea level rise. The rate of SLR lies between 0.829 mm/yr to 2.021 mm/yr. The highest rate of SLR is at Teluk Ewa, Langkawi and the lowest is at Penang. The future projections of the trend line for an estimate SLR in the year 2050 and 2100, for all the selected stations exhibit an increment in sea level rise. In 2050, the highest incremental SLR is 9.175 cm which is at Teluk Ewa, Langkawi while the lowest incremental value is 3.994 cm at Penang. Subsequently, in 2100 the highest increment in SLR is 19.595 cm while the lowest increment is 8.395 cm at Teluk Ewa, Langkawi and Penang respectively. The trend analysis and the future projection also prove that the Straits of Malacca will experience a rise in sea level in 2050 and 2100.

ABSTRAK

Kenaikan paras air laut pada masa hadapan dijangka akan memberi impak terhadap sistem pesisir pantai Malaysia seperti banjir, hakisan pantai dan kemasukan air masin. Kajian ini menganalisa variasi trend kenaikan paras air laut di lokasi-lokasi terpilih di sepanjang Pantai Barat Semenanjung Malaysia. Di samping itu, kadar kenaikan paras air laut pada tahun 2050 dan 2100 untuk setiap lokasi akan diramal. Kajian ini juga mengkaji trend kenaikan paras air laut di sepanjang Selat Melaka. Data purata paras air laut daripada rekod terdahulu telah digunapakai di dalam analisa ini. Ujian Mann-Kendall bukan parametrik dilakukan bagi menentukan trend dan variasi kenaikan paras air laut. Daripada analisa yang dijalankan, didapati kesemua stesen di sepanjang Pantai Barat Semenanjung Malaysia (iaitu: Teluk Ewa Langkawi, Penang, Lumut, Port Klang, Tanjung Keling Melaka, dan Kukup Johor) menunjukkan trend yang meningkat pada paras air laut. Kadar kenaikan paras air laut adalah di antara 0.829 mm/tahun sehingga 2.021 mm/tahun. Teluk Ewa Langkawi mencatatkan kadar tertinggi bagi kenaikan paras air laut dan Pulau Pinang mencatatkan kadar kenaikan paras air laut yang terendah. Unjuran masa hadapan garisan graf menunjukkan paras air laut akan meningkat pada tahun 2050 dan 2100 bagi kesemua stesen terpilih. Pada tahun 2050, Teluk Ewa, Langkawi akan mengalami kenaikan paras air tertinggi iaitu 9.175 cm dan Pulau Pinang mencatatkan kenaikan paras air laut terendah iaitu 3.994 cm. Selanjutnya, pada tahun 2100, paras air laut mencatatkan peningkatan tertinggi iaitu sebanyak 19.595 cm dan peningkatan terendah iaitu 8.395 cm di Teluk Ewa, Langkawi dan Pulau Pinang masing-masing. Hasil analisa dan unjuran masa hadapan yang telah dibuat juga membuktikan Selat Melaka akan mengalami kenaikan paras air laut pada tahun 2050 dan 2100.

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CHAPTER 1

INTRODUCTION

1.1 Research Background

Sea level can change, both globally and locally, due to (i) changes in the shape of the ocean basins, (ii) changes in the total mass of water and (iii) changes in water density. Global mean sea level (MSL) has been rising since the end of the last ice age almost 18,000 years ago. Factors leading to sea level rise (SLR) under global warming include both increases in the total mass of water from the melting of land-based snow and ice, and changes in water density from an increase in ocean water temperatures and salinity changes.

As the world's oceans rise, low-lying coastal areas will disappear. Flooding of coastal areas will become more common and more severe as storm surges have easier access to these lower-lying areas. The occurrence of extreme high water events related to storm surges, high tides, surface waves, and flooding rivers will also increase.

Flooding and loss of land will have significant impacts on humans, wildlife, and entire ecosystems.

Coastal areas are also important economic areas as they are resource-rich. Tourism, aquaculture, fisheries, agriculture, forestry, recreation, and infrastructure will all be strongly affected by the effects of rising sea level. Another effect of sea level rise is contamination of groundwater resources through salt water intrusion. Increasing sea levels and flooding will have a number of impacts on terrestrial water storage in addition to seawater intrusion. These include rising water tables from salt water intrusion, erosion, and impeded drainage.

The UN Intergovernmental Panel on Climate Change (IPCC) Response Strategies Working Group Scientists, 1990 mentioned that from the officials list of some seventy (70) nations have expressed their views on the implications of sea level rise and other coastal impacts of global climate change at Coastal Zone Management Subgroup workshops in Miami and Perth. They indicated that in several noteworthy cases, the impacts could be disastrous; that in a few cases impacts would be trivial; but that for most coastal nations, at least for the foreseeable future, the impacts of sea level rise would be serious but manageable if appropriate actions are taken.

The UN IPCC 1990 Report also highlighted the needs and the demand of overcoming the future scenario where research on the impacts of global climate change on sea level rise should be strengthened, a global ocean observing network should be developed and implemented, and data and information on sea level change and adaptive options should be made widely available.

1.2 Problem Statement

Malaysia is a coastal nation, rich in biodiversity and natural resources. The country covers an area of 329,750 km² with a coastline of 4809 km and is divided into two landmasses that are separated by the South China Sea. Peninsular Malaysia, in the west, has an area of 131,590 km² and a coastline of 2031 km. Peninsular Malaysia composes of 11 states and the Federal Territory of Kuala Lumpur. Two other states, Sabah and Sarawak, occupying an area of 73,711 km² and 124,449 km² respectively, and the Federal Territory of Labuan are located in the northwestern coast of Borneo island. Sabah has a coastline of 1743 km while Sarawak has a coastline of 1035 km. A map of the Malaysia coastline is shown in Figure 1.1.



Figure 1.1: Map of Malaysia Coastline
Source: DID, 2000

The major towns, ports, large agriculture and aquaculture projects of Malaysia's coast contribute significantly to the nation's economic development. It is anticipated that the physical and economic impact for the whole nation of a greenhouse-induced sea level rise could be devastating.

According to J.E Ong (2000) as quoted from Geyh et.al (1972), Kamaludin (1989) and Peltier & Tushingham (1989), there is good geological evidence that showed over the last 5,000 or so years, sea level around Malaysian coast has been falling at a mean rate of about 1 mm/yr and the global tidal level is dropping at 2.4 ± 0.9 mm/yr. Meanwhile, the sedimentation rate which appears to be playing a critical role in relative sea level change in Malaysia is in the region of a few millimeters per year. In more recent finding, Malaysia sea level has risen at an average rate of 1.25 mm/yr over 1986 to 2006 (Initial National Communication, 2000 and National Coastal Vulnerability Index Study, DID, 2007). All of the above findings are signals to show that Malaysia coastal system might be vulnerable to SLR.

Future SLR would be expected to have a number of impacts, particularly on Malaysia coastal systems. The stronger waves accompanying a rise in sea level will destroy the beaches and increase coastal erosion. Beside coastal erosion, the other major threat of SLR is inundation. About 12 percent of Peninsular Malaysia's area, where the western low plains of muddy sediment are home to 2.5 million people, is flood prone (J.E Ong, 2000). Further more, SLR will also lead to salt water intrusion, changes in surface water quality and groundwater characteristics, increased loss of life, property and coastal habitats due to flooding, impacts on agriculture and aquaculture through decline in soil and water quality, and loss of tourism, recreation, and transportation functions.

Therefore, there is indication of the urgency for Malaysia as one of the coastal nations to begin the progression of adapting to sea level rise not because there is an awaiting catastrophe, but because there are opportunities to avoid unpleasant impacts by acting now, opportunities that may be lost if the process is delayed. Unfortunately, there is lack of official indication or measurement has been done in Malaysia on SLR. Hence, how should Malaysians prepare for sea level rise? Thus, this particular study is required to analyze the trend variation of SLR for selected locations along west coast of Peninsular Malaysia and to predict SLR in the year 2050 & 2100 so that the consequences of SLR can be reduced through a proper management and implementation of adaptation and mitigation measures.

1.3 Study Area

In this study, six locations along the west coast of Peninsular Malaysia are selected for the purpose of trend analysis. The locations are Langkawi, Penang, Lumut, Port Klang, Tanjung Keling and Kukup. The locations are selected based on the existing tidal gauge stations along the west coast of Peninsular Malaysia. Figure 1.2 below shows the selected locations.

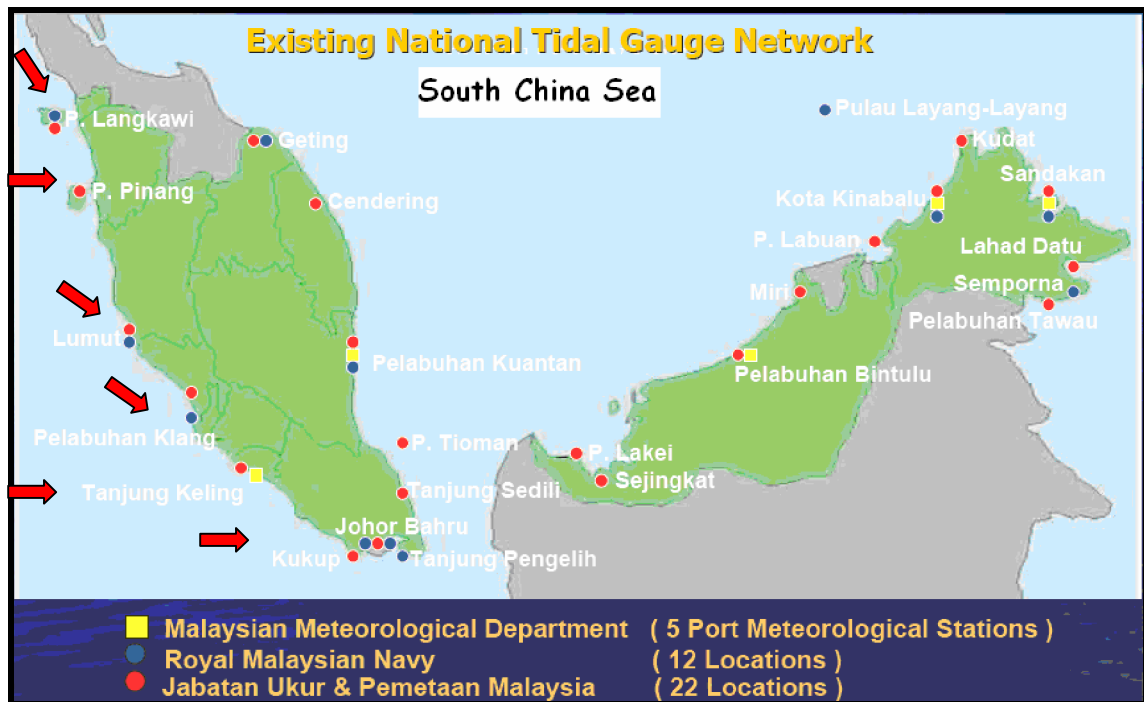


Figure 1.2: Study area locations

1.4 Objectives of Study

The objectives of this study are:

- i. To analyze the trend variation of sea level rise for selected locations along the west coast of Peninsular Malaysia;
- ii. To predict sea level rise for these locations in the year 2050 and 2100.
- iii. To study the trend of sea level rise throughout the Straits of Malacca.

1.5 Scope of Study

The scope of this study can best be described as follows:

- i. A review of all literatures related to trend analysis methodologies and to apply the most suitable technique in the analysis for the six selected stations along the west Coast of Peninsular Malaysia (i.e. Langkawi, Penang, Lumut, Port Klang, Tanjung Keling and Kukup).
- ii. Collection of data (tidal records) for all selected stations will be used for the purpose of trend analysis.
- iii. Conduct of the selected methodology for the sea level rise trend analysis and prediction for the year 2050 and 2100.
- iv. Determination of the general trend of SLR variation throughout the Straits of Malacca.

1.6 Significance of Study

The findings from this study are expected to provide:-

- The trend/pattern of SLR for each of the selected stations along west coast of Peninsular Malaysia.
- The rate of SLR for each of the selected stations along west coast of Peninsular Malaysia.
- The prediction rate of future SLR at the selected stations in the year 2050 and 2100.
- The variation of the SLR rate in the Straits of Malacca.

The results will impose as a strong signal of SLR threat to the west coast of Peninsular Malaysia and will lead to the recommendations of adaptive measures to mitigate the SLR in the future.

REFERENCES

- Algirdas Budrevicius (2004). *Quantitative Forecasting Methods in Library Management*, Faculty of Communication, Vilnius University.
- Bates, B.C., Z.W. Kundzewicz, S. Wu and J.P. Palutikof, Eds. (2008). *Climate Change and Water*. Technical Paper of the Intergovernmental Panel on Climate Change, IPCC Secretariat, Geneva.
- Bindoff, N.L., J. Willebrand, V. Artale, A. Cazenave, J. Gregory, S. Gulev, K. Hanawa, C. Le Quéré, S. Levitus, Y. Nojiri, C.K. Shum, L.D. Talley and A. Unnikrishnan (2007). Observations: Oceanic Climate Change and Sea Level In: *Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*.
- Burkay Seseogullari, Ebru Eris and Ercan Kahya (2007). *Trend Analysis of Sea Levels Along Turkish Coast*. Hydraulic Division, Civil Engineering Department, Istanbul Technical University.
- Department of Irrigation and Drainage Malaysia, Ministry of Natural Resources and Environment (2007). *National Coastal Vulnerability Index Study – Phase 1 (Final Report)*.

- Douglas C. Montgomery, George C. Runger and Norma Faris Hubele (2004). *Engineering Statistic, Third Edition*. Arizona State University. John Wiley and Sons Inc.
- Gilbert, R.O. (1987). *Statistical Methods for Environmental Pollution Monitoring*. Van Nostrand Reinhold, New York.
- Hadikusumah (1995). *Study on Sea Level Rise in The Western Indonesia*. International Journal, Research and Development Center for Oceanology, Indonesian Institute of Science, Jakarta, Indonesia.
- Harry Storch, Nigel Downes, Nguyen Xuan Thinh, Hans-Peter Thamm, Ho Long Phi, Tran Thuc, Nguyen Thi Hien Thuan, Guenter Emberger, Manfred Goedecke, Joern Welsch, and Michael Schmidt (2009). *Adaptation Planning Framework to Climate Change for Urban Area of Ho Chi Minh, Vietnam*, Fifth Urban Research Symposium 2009.
- Hulme, M. and Sheard, N. (1999) *Climate Change Scenarios for Indonesia*. Climatic Research Unit, Norwich, UK, 6pp.
- Hülya Boyacioglu and Hayal Boyacioglu (2006). *Water Quality Evaluation And Trend Analysis In Buyuk Menderes Basin, Turkey*. Faculty of Engineering, Department of Environmental Engineering, Dokuz Eylul University.
- IPCC WGI Fourth Assessment Report (2007). *Climate Change 2007: The Physical Science Basis Summary for Policymakers*.
- James G. Titus et.al (1996). *The Risk of Sea Level Rise*. U.S Environmental Protection Agency.

James G. Titus (1998) *Rising Seas, Coastal Erosion, And The Takings Clause: How To Save Wetlands And Beaches Without Hurting Property Owners*. Volume 57, Number 4, Maryland Law Review.

J. E. Ong (2000). *Vulnerability of Malaysia To Sea-Level Change*. Centre for Marine and Coastal Studies, Universiti Sains Malaysia, Penang, Malaysia.

Kendall, M.G. (1975). *Rank Correlation Methods, Fourth Edition*, Charles Griffin, London.

Meehl, G.A., T.F. Stocker, W.D. Collins, P. Friedlingstein, A.T. Gaye, J.M. Gregory, A. Kitoh, R. Knutti, J.M. Murphy, A. Noda, S.C.B. Raper, I.G. Watterson, A.J. Weaver and Z.-C. Zhao (2007): Global Climate Projections. In: *Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*.

Report of the Coastal Zone Management Subgroup (1990). *Strategies For Adaption To Sea Level Rise*. Intergovernmental Panel on Climate Change Response Strategies Working Group.

Susmita Dasgupta, Benoit Laplante, Craig Meisner, David Wheeler and Jian Yan (2007). *The impact of Sea Level Rise on Developing Countries; a Comparative Analysis*. New World Bank Working Paper.

UN Environment Programme (UNEP) Year Book, 2008.

UN-HABITAT's new *State of the World's Cities Report 2008/9: Harmonious Cities*.

UN-HABITAT Global Urban Observatory, 2008.

W. Chingombe, J.E.Gutierrez, E. Pedzisai and E. Siziba (2006). *A Study Of Hydrological Trends And Variability Of Upper Mazowe Catchment-Zimbabwe.*

William Mendenhall et.al (2003). *Probability and Statistics.* Thomson Learning, USA.

Yoshiki Saito, Niran Chaimanee, Thanawat, Jarupongsakul and James P.M. Syvitski (2007). *Shrinking Megadeltas in Asia: Sea-level Rise and Sediment Reduction Impacts from Case Study of the Chao Phraya Delta.* Geological Survey of Japan, AIST.

Zainal Akamar Bin Harun (2008). Paper Presenter for Coastal Vulnerability Ministry of Natural Resources and Environment (Nre), *Second National Conference on Extreme Weather and Climate Change: Understanding Science and Risk Reduction.*